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of

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for

SYSTEM FOR TESTING A SEMICONDUCTOR DEVICE

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1 1. Related Applications.

2 This is a divisional application of US Patent Application Serial No. 09/123,633,
3 filed on July 28, 1998, titled "THERMALLY CONDUCTIVE INTERPOSER AND
4 METHOD" which is incorporated herein by reference.

5
6 **BACKGROUND OF THE INVENTION**

7 2. **The Field of the Invention**

8 This invention is in the field of semiconductive device technology. More
9 specifically, this invention is in the field of interposers for electrically connecting
10 semiconductive devices to an electrical apparatus.

11
12 3. **The Relevant Technology**

13 A semiconductive device is often electrically coupled to an electrical apparatus such
14 as a computer through the use of an interposer. In one such process, the semiconductive
15 device is connected to the interposer, which is then inserted into the socket of the electrical
16 apparatus. The socket may be mounted on the motherboard of a computer, for example.
17 Thus, the semiconductive device communicates electrically through the interposer with the
18 electrical apparatus. Typical interposers currently employed in the coupling of
19 semiconductive devices to electrical apparatuses are comprised of an FR4 fiberglass material,
20 or the like, having electrically conductive metal lines or traces thereon.

21 The term "semiconductive device" extends to any device or assembly that includes
22 circuitry defined in a semiconductive material, and further extends to a chip package that
23 includes semiconductive material. The external and additional structure of a package
24 assembly may be used, for example, for mounting the semiconductive device to a printed
25 circuit board or other external circuitry, for establishing electrical connection between the
26 semiconductive device and external circuitry, for improving the ease of handling or

1 transporting the semiconductive device, and/or for protecting the semiconductive device
2 from environmental conditions. Many chip packages include a lead frame that extends
3 beyond the body thereof. The lead frame typically includes an array of electrical leads that
4 extend from the internal circuitry of the integrated circuit to the exterior portion of the chip
5 package where they are exposed to the surroundings.

6 Frequently, after a semiconductive device is manufactured, a testing process is
7 conducted on the semiconductive device by subjecting it to a preselected set of input
8 conditions in order to measure its response or other parameters. Testing of an integrated
9 circuit package that includes a lead frame assembly is conventionally conducted by providing
10 temporary electrical communication between the leads and testing circuitry. For example,
11 such temporary electrical connection may be established by using a set of probes, pins,
12 sockets, or the like, to contact the leads. The integrated circuit package may be clamped or
13 otherwise secured in position during the testing operation in order for the leads to remain in
14 electrical contact with the corresponding probes, pins, sockets, etc., of the testing circuitry.

15 Semiconductive devices, such as DRAMs and SRAMs, undergo significant stresses
16 when in use. Particularly modern, high speed, advanced-integration semiconductive devices
17 generate a significant amount of heat during use. This heat can degrade and slow down
18 semiconductive devices. For example, testing of semiconductive devices to determine the
19 quality and capability of the devices can generate such heat within the devices that the testing
20 process itself damages the devices. Typical fiberglass interposers do not dissipate heat
21 sufficient to protect semiconductive devices from the potential of damage caused by the heat
22 generated during use of the device.

23 In addition, typical fiberglass interposers are made of glass fibers and epoxy resin.
24 The resulting interposer has a coefficient of thermal expansion which is incompatible with
25 typical semiconductive devices. The coefficient of thermal expansion of the fiberglass is
26 often significantly greater than that of the semiconductive device.

1 As a result of this thermal expansion incompatibility, shear stresses develop in the
2 interface between the interposer and the semiconductive device when the semiconductive
3 device becomes hot. These shear stresses can result in a severing of the electrical connection
4 between the interposer and the semiconductive device. While it is possible to ameliorate the
5 effects of shearing through a process known as wire bonding, this process adds additional
6 complexity and expense. Furthermore, the organic material within FR4 fiberglass interposers
7 absorbs moisture, causing the interposers to degrade.

8 There is therefore a need in the art for an improved interposer which assists in
9 protecting a semiconductive device coupled to the interposer from the potential damage
10 caused by significant amounts of heat generated by the semiconductive device. There is also
11 a need in the art for an improved interposer which prevents shear stress from severing the
12 electrical connection between the interposer and the semiconductive device.

SUMMARY OF THE INVENTION

1
2 An interposer of the present invention is comprised of (i) a substrate comprised of
3 an electrically insulating, thermally conductive ceramic material; and (ii) an electrical
4 conductor on the substrate having a receiving end for connecting to a semiconductive device
5 and a terminal end for connecting to an electrical apparatus. The semiconductive device is
6 electrically coupled to the electrical apparatus when the semiconductive device is connected
7 to the receiving end of the electrical conductor and the terminal end of the electrical
8 conductor is connected to the electrical apparatus. The invention also includes thermally
9 conductive connections between the semiconductive device and an interposer.

10 In one embodiment, a thermally conductive connector connects the semiconductive
11 device, such as an SRAM, DRAM, or integrated circuit device, to the interposer such that
12 a portion of the semiconductive device is exposed to the atmosphere to thereby dissipate heat
13 to the atmosphere. Both the thermally conductive interposer and the thermally conductive
14 connector act as heat sinks to conduct heat from the semiconductive device to the ambient,
15 thereby protecting the semiconductive device from overheating. The interposer preferably
16 has a coefficient of thermal expansion which is substantially similar to the coefficient of
17 thermal expansion of a semiconductive device on the interposer, thereby preventing shearing
18 of the electrical connection between the semiconductive device and the interposer.

19 In one embodiment, the semiconductive device is fastened temporarily and
20 removably to the interposer and the interposer is coupled to an electrical apparatus. In
21 another embodiment, the semiconductive device is permanently coupled to the interposer.
22 As an example of a connector, a biasing clip enables quick and convenient placement and
23 removal of semiconductive devices on the interposer. The interposer may be permanently
24 or removably coupled to the electrical apparatus, depending on the desired application.

1 These and other features of the present invention will become more fully apparent
2 from the following description and appended claims, or may be learned by the practice of the
3 invention as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages of the invention are obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

Figure 1 is a perspective view of an interposer kit of the present invention showing one trace array empty, one trace array having a semiconductive device thereon, and one trace array having a semiconductive device thereon with a biasing connector coupling the semiconductive device to the interposer.

Figure 2 is a bottom surface view of a semiconductive device.

Figure 3 is a perspective view of a biasing connector of the present invention.

Figure 4 is a perspective view of another embodiment of a biasing connector of the present invention.

Figure 5 is a perspective view of the interposer kit shown in Figure 1 with an additional biasing connector and semiconductive device placed thereon.

Figure 6 is a cross-sectional, cut-away view of the semiconductive device and the interposer shown in Figure 1.

Figure 7 is a cross-sectional, cut-away view of another embodiment of a semiconductive device and interposer.

Figure 8 is a cross sectional, cut away view of the interposer of Figure 1 having an insulating layer on the intermediate portion of a conductor thereof.

Figure 9 is a schematic view of an electrical apparatus shown as receiving the interposer kit shown in Figure 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference now to Figures 1 and 2, the present invention relates to an interposer system 10 comprising (i) an interposer 12; and (ii) a connector 14 for connecting a semiconductive device 16 to interposer 12. Interposer 12 is configured to electrically couple semiconductive device 16 to an electrical apparatus (not shown in Fig. 1), such as a testing apparatus which monitors, tests or evaluates device 16, by for example storing information on device 16 and retrieving information from device 16.

Interposer 12 is electrically coupled to the electrical connections 17 of device 16, the bottom surface of which is shown in Figure 2, and to electrical connections on an electrical apparatus, thereby electrically coupling semiconductive device 16 to the electrical apparatus. By coupling semiconductive devices 16 on interposer 12, and coupling interposer 12 to the electrical apparatus, the electrical apparatus may perform a variety of functions upon the semiconductive devices, while the semiconductive devices are protected from overheating by the heat dissipating qualities of interposer 12.

Interposer 12 and preferably, connector 14, are thermally conductive. As shown in Figure 1, system 10 preferably exposes semiconductive device 16 partially to the open atmosphere, rather than completely covering devices 16 with a connector, allowing heat to dissipate to the atmosphere directly from semiconductive device 16. In addition, heat is transferred through thermally conductive interposer 12 and connector 14 from semiconductive device 16, then dissipated to the atmosphere. The thermal conductivity of interposer 12 and connector 14, along with the configuration of interposer 12 and connector 14 are significant advantages within the art.

Interposer 12 will now be discussed in additional detail. Interposer 12 is comprised of a substrate 18 and a plurality of electrical conductors 20 on substrate 18. Substrate 18 is comprised of an electrically insulating material. Substrate 18 also conducts heat, thereby dissipating heat away from device 16 connected to substrate 18. When exposed to the high

1 temperatures generated by advanced high density, high integration devices 16, substrate 18
2 does not warp or bow. Substrate 18 has formed thereon electrical conductors 20, such as
3 metal traces. Substrate 18 also preferably has substantially similar thermal expansion
4 properties as semiconductor device 16, such as a substantially similar coefficient of thermal
5 expansion as that of semiconductive device 16. By having substantially similar thermal
6 expansion properties, shear stress is reduced in the physical connections between device 16
7 and interposer 12 so as to prevent a severing of the electrical connection between device 16
8 and interposer 12.

9 In one embodiment, substrate 18 is comprised of a ceramic material, such as an
10 inorganic ceramic material. Examples of ceramic materials used in the production of
11 substrate 18 include glass. Many forms of glass may be used, including glass comprising
12 silicates, silica, silicon oxide, phosphates, or borates, or derivatives thereof. Such glass may
13 be doped with metal, an oxide or other elements, so long as it remains electrically insulative.
14 Glass may be formed by fusing silica with a basic oxide, for example. Borophosphosilicate
15 glass is one example of a material useful for substrate 18. Inorganic forms of glass are
16 preferable. Glass materials often have substantially similar thermal expansion properties as
17 semiconductive devices 16, which are often substantially comprised in the most part of
18 silicon or other semiconductive material.

19 In addition to glass, other ceramics useful in the present invention as substrate 18
20 include alumina, aluminum nitrides, nonmetallic nitrides, nonmetallic carbides, single oxide
21 ceramics, mixed oxide ceramics, and mixtures and derivatives thereof. As used throughout
22 this specification and the appended claims, the term "nonmetallic nitrides" includes boron
23 nitrides, silicon nitrides and other transitional element nitrides. Alumina, for example, may
24 be used alone or in combination with silica or silicates, for example, because alumina resists
25 harsh environments and also dissipates heat.

1 Other examples of ceramics useful in the present invention for substrate 18 include
2 glass ceramics, such as nucleated glass having a nonporous, substantially crystalline
3 structure, devitrified ceramics, or vitro ceramics. In one embodiment, glass ceramics are
4 fine-grained substantially crystalline materials made through controlled crystallization from
5 glass compositions containing nucleating agents. Thus, in one embodiment, substrate 18
6 comprises a material selected from the group consisting of glass, alumina, glass ceramic,
7 aluminum nitride, nonmetallic nitride, nonmetallic carbide, and mixtures and derivatives
8 thereof. Other possible, but less preferred ceramics for substrate 18 include refractories such
9 as steatite and mullite.

10 Glass and other ceramics are preferably provided in a substantially homogeneous
11 form for substrate 18, as opposed to the heterogeneous mixture of fibers and epoxy found in
12 FR4 fiberglass. Glass and other ceramics are also preferably provided in substrate 18 in a
13 substantially planar (i.e., flat) sheet, as shown in Figure 1.

14 As shown in Figure 1, interposer 12 includes a plurality of arrays 22, 24, 26 of
15 electrical conductors 20 thereon. Each electrical conductor 20 has a receiving end 28 for
16 connecting to a corresponding terminal 30 of an electrical conductor 32 on the bottom
17 surface of semiconductive device 16 as shown in Figure 2. Each electrical conductor 20 on
18 substrate 18 further comprises a terminal end 34 for connecting to an electrical apparatus.
19 An intermediate portion 36 of conductor 20 extends between receiving end 28 and terminal
20 end 34 of each conductor 20. The connection of terminal end 34 to the electrical apparatus
21 may be permanent or removable.

22 An interposer of the present invention may comprise a single conductor or a plurality
23 of conductors. The interposer may have a single array of conductors or may have a plurality
24 of arrays, such as arrays 22, 24, 26 as shown in Figure 1. Each array may have as many
25 conductors as needed to electrically couple a particular semiconductive device, such as
26 device 16, to an electrical apparatus. Conductors may have a variety of different

1 configurations any of which are designed to electrically couple a semiconductive device to
2 an electrical apparatus. Heat dissipates to the environment through the conductors and from
3 the conductors through the substrate to the ambient.

4 In one embodiment, the semiconductive device is permanently coupled to the
5 interposer. The semiconductive device may be permanently coupled to the interposer
6 through the use of an adhesive, for example, which is another example of a connector. In an
7 underfilling process, adhesive is placed around the edges of semiconductive device 16
8 mounted on interposer 12, then the adhesive is permitted to wick through capillary action
9 between interposer 12 and semiconductive device 16. This process can be repeated until the
10 desired bond is achieved between interposer 12 and the semiconductive device 16. This
11 underfilling process is often used for flip chips, for example. Preferably, the adhesive is a
12 thermally conductive adhesive, such as a silver-filled epoxy, or a tape having acrylics filled
13 with alumina or aluminum nitride with a matrix in resin. The thermally conductive adhesive
14 enhances heat dissipation away from semiconductive device 16. Adhesives may be applied
15 using a screen printing process, for example.

16 In another embodiment, semiconductive device 16 is removably coupled to
17 interposer 12, such as when it is desired to test device 16 by coupling device 16 to testing
18 apparatus which monitors, tests, and/or evaluates device 16. Preferably, when removability
19 is desired, connectors such as resilient biasing connectors 14 are employed. As shown in
20 Figure 1, biasing connector 14 connects device 16 to interposer 12 such that a substantial
21 portion of device 16 is exposed to the open environment, thereby assisting in dissipating heat
22 from device 16.

23 With reference now to Figures 3, 4, and 5, various embodiments of biasing
24 connectors are demonstrated. As shown in Figure 3, connector 14 comprises a resilient clip
25 having a top plate 38, a bottom plate 40, and an intermediate portion 42 coupling top plate

38 to bottom plate 40. Connector 14 may be employed to resiliently, removably bias semiconductive device 16 against interposer 12.

Another embodiment of a connector 44 is demonstrated in Figure 4. Connector 44 comprises a resilient clip having an upper plate 46, a lower plate 48 and an intermediate portion 50 coupling upper plate 46 to lower plate 48. Each of plates 46, 48 include a bow in the central portion thereof. The bow in plates 46, 48 allowing front ends 52, 54 of clip 44 to be readily biased open and closed manually for placement over device 16 and substrate 12.

As shown in Figure 5, in one embodiment one connector 14 is used for a single semiconductive device 16, whereas in another embodiment a single connector 56 is used to couple a plurality of semiconductive devices 16 to interposer 12. Connector 56 may be in the shape of clip 14, clip 44, or a variety of other clips or other configurations. A variety of different designs of connectors may be employed in the present invention such as other clips, crimps, clamps and a variety of other connectors having shapes and configurations which allow them to resiliently, removably bias semiconductive devices 16 to interposer 12.

In a preferred embodiment, heat is also conducted through a thermally conductive connector to the environment. Biasing connectors 14, 44, and 56 are preferably comprised of a resilient, heat dissipating material such as copper, copper alloy, or another metal. The connectors are also insulated from the electrical connections on devices 16, such as by being further comprised of or coated with an electrically insulating material, such as glass or polymer or by being placed on electrically insulating portions of devices 16. The connectors thus resiliently, removably bias semiconductive devices 16 against interposer 12 while simultaneously assisting in dissipating the heat generated by devices 16 in conducting the heat to the atmosphere. These connectors do so in a manner which allows a portion of the device itself to be exposed to the atmosphere, thereby increasing the dissipative qualities of system 10.

1 Connectors 14, 44, 56 dissipate heat because they are in intimate thermal contact
2 with devices 16 and because they are comprised of a thermally conductive material.
3 Connectors 14, 44, 56 and other such connectors may be placed on device 16 manually or
4 automatically. One advantage of such connectors over an underfilling process is that the
5 connectors do not need a delay time in which wicking occurs and they avoid the further delay
6 of repeated applications, as well as delays associated with curing of the adhesive.

7 Connectors 14, 44, 56 or a variety of substantially similar connectors may also be
8 employed to assist in permanently coupling devices 16 to substrate 18, thereby providing
9 heat dissipation. For example, it is possible to employ both an adhesive, such as a thermally
10 conductive adhesive and a connector, such as connector 14, 44, or 56 to permanently couple
11 semiconductive device 16 to interposer 12. This may be accomplished, for example, by
12 placing adhesive between substrate 18 and semiconductive device 16 with a connector 14,
13 44, or 56 to couple both substrate 18 and device 16 together and/or by placing the adhesive
14 between connector 14, 44, or 56 and substrate 18, for example. Adhesive may also be placed
15 between connector 14, 44, or 56 and device 16 so long as the electrical connections between
16 connector 14, 44, or 56 and device 16 are preserved.

17 Conductors 20 may be conventionally formed on substrate 18 by being attached or
18 deposited thereon. For example, a metal can be sputtered onto substrate 18, followed by a
19 patterning process to define conductors 20. Other conventional metallizing or metal line
20 deposition processes can also be used. In one embodiment, substrate 18 is initially etched,
21 after which the etched portion is metallized, by metal deposition and a metal line patterning
22 process. Metal deposition and photolithographic metallization processes may be used to etch
23 fine line widths and to place conductors in dense arrays on substrates to form interposers.

24 As shown in Figure 6, in one embodiment, electrical conductor 20 has a bumped
25 receiving end 28 which projects from the upper surface of substrate 18. In this embodiment,
26 semiconductive device 16 includes a corresponding electrical conductor 32 having a bumped

1 terminal 30 which couples to receiving end 28, thereby forming a connection between bump
2 30 and bump 28 when device 16 and interposer 12 are connected together such that bumps
3 28 and 30 interface. This creates a physical connection between substrate 18 and device 16.
4 This configuration allows bumps 28, 30 to slide against one another, permitting convenient
5 coupling of bumps 28, 30 together as well as removal of bumps 28, 30 one from another.

6 In another embodiment, as shown in Figure 7, the electrical connection between an
7 interposer 59 and a semiconductive device 58 is created by providing for a complimentary,
8 male/female connection between device 58 and interposer 59. Although interposer 59 is
9 shown as comprising the female fitting, the interposer may comprise the male fitting, as
10 shown in Figure 6 with protruding bumped receiving end 28, while the semiconductive
11 device comprises the female fitting which is formed in a recess of the semiconductive device.

12 In the embodiment shown in Figure 7, interposer 59 comprises a substrate 60 having
13 a recess 62 therein. A conductor 64 such as a metal trace is placed on substrate 60 such that
14 a receiving end 66 of conductor 64 is disposed within recess 62, which is below the upper
15 surface of substrate 60, allowing a male connecting terminal 68 of a conductor on
16 semiconductive device 58 to be electrically coupled with receiving end 66 by being placed
17 therein. Conductor 64 also has a terminal end (not shown) for connecting to an electrical
18 apparatus. A connector such as connector 14, 44, or 56 may then be placed to bias device
19 58 towards substrate 60 to thereby retain the electrical connection between bump 68 and
20 recessed receiving end 66. It will be appreciated that the male/female complimentary fit
21 shown in Figure 7 would be advantageous because of the structural integrity and non-slip
22 design derived therefrom.

23 According to one method of manufacturing interposer 12 or 59, a substrate 18 or 60
24 of the present invention is provided comprising a ceramic material. At least one electrical
25 conductor 20 or 64 is then coupled onto the substrate. In one embodiment, recess 62 is
26 formed within substrate 60, such as through etching, and at least a portion of conductor 64

1 is placed within the recess 62. A recess may be formed to receive receiving end 66, as shown
2 in Figure 7, the entire conductor, an intermediate portion of conductor 64 and end 66, or a
3 variety of other portions of conductor 64.

4 As yet another feature of the invention, as shown in Figure 8, it is possible to form
5 a layer 69, such as a coating, of an electrically insulating material on the intermediate
6 portion 36 of electrical conductor 20 of interposer 12. The electrically insulating material
7 for layer 69 may comprise an electrically insulating material, such as a polymer or resin. In
8 one embodiment, the electrically insulating material is thermally conductive, such as a
9 ceramic material such as described above (e.g., glass, aluminum nitride or alumina), for
10 example. Thus, in one embodiment, layer 69 electrically insulates conductor 20 from contact
11 with an electrical conductor, such as an uninsulated connector, and simultaneously aids in
12 heat dissipation.

13 With reference now to Figure 9, interposer 12 having semiconductive devices 16
14 electrically coupled thereto through the use of connectors 14, 56 is electrically coupled to an
15 electrical apparatus 70 such as a testing apparatus shown in a diagrammatic view in Figure 9.
16 Interposer 12 may be permanently or removably coupled to apparatus 70.

17 As used throughout this specification and the appended claims, the term "electrical
18 apparatus" refers to an apparatus which electrically couples to a semiconductive device.
19 Examples of such apparatuses include a computer, program logic controller, electronic game
20 assembly, a controlling module, and a testing apparatus which monitors, tests, or evaluates
21 a semiconductive device. The testing apparatus may be a computerized testing apparatus,
22 for example.

23 Apparatus 70 includes a socket, such as a printed circuit board socket, having
24 electrical terminals onto which terminal ends 34 of conductors 20 of interposer 12 are placed.
25 After terminal ends 34 of interposer 12 are placed into the socket, an electrical connection